学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Characteristics of stiffness and strength mobilization in steel slag-mixed dredged clays from immediately after mixing

(混合直後からのスラグ混合浚渫粘土の剛性と強度発現特性)

Dredged soils need to be pre-treated prior to reuse in construction due to its high water content and unfavorable engineering properties. A possible solution to improve the properties is solidification by mixing several binders such as cement, lime, and ground granulated blast furnace slag (GGBS). Reusing of the dredged soils, however, comes with technical and economical challenges and optimization in design requires further research. This study focuses on one of such binders of waste origin, the steel slags deriving from steel processing plants, which are often used as a substitute of aggregates in road construction due to their durability. The presence of Portlandite $Ca(OH)_2$ in steel slag leads to potential hydration capacity, and this can be exploited to improve engineering properties of high-water content dredged clays.

From previous research, the various factors affecting the strength mobilization at the stiff stage was identified; the slag content, the particle size of slag, curing time and addition of alkali activators such as $NaOH$ and/or Na_2SiO_3. Despite these general pieces of knowledge, the continuous stiffness and strength mobilization and the correlation between them in different steel slag-mixed dredged clays from immediately after mixing have not been fully studied. Such a study will help find suitable materials and mixing conditions at an early stage of engineering work. There is still a lack of a guide to which kind of combination of steel slag and clay leads to greater strength development. Different types of dredged clay and steel slag, and their physico-chemical interactions that result in stiffness and strength mobilization need to be comprehensively and systematically studied.

The strength and stiffness mobilization characteristics of four dredged clays from Japan, named A, B, C and D, mixed with two steel slags, S1 and S2, were continuously investigated from immediately after mixing to 28 days of curing by using direct shear apparatus and bender elements. In addition to the dredged clays, a non-marine clay, Kasaoka clay (K), was also used to further investigate the strength and stiffness mobilization. Unlike in more conventionally adopted unconfined compression testing, these tests could be applied to mixed specimens since initial un-cemented states, and are useful in detecting the transition of the slurry-like states to more solid states. The stiffness and strength mobilization was observed to have three distinct stages. In the second, main stage of evolution, the mobilization rates were found to be loosely correlated to the amorphous silica amount. The correlation was also influenced by the $Ca(OH)_2$ amount in slag. The results can be used to screen out clays that are hard to solidify in the medium term, based on quick on-site measurement of amorphous silica amount. For quality control in practice, the strength–stiffness relationship was critically examined as

means to assess the strength with non-destructive stiffness probes. A close observation revealed that representing a wide range of curing time and mixing conditions by a single line, as proposed in existing studies, could be misleading. A new interpretation of the relationship is proposed.

Further study was made on potential factors affecting the stabilization processes, such as the strength measurements by different test methods, the influence of water salinity, and the grain size and shape. The good agreement of the strength from 3 days to 28 curing obtained by direct shear test (DST) and unconfined compression test (UCT) was identified. The initial solidification behavior depends on the pore water salinity. Under the same gradation, the strength and stiffness induced by S1 and S2 were even more different, suggesting that the gradation is not the cause of the observed difference. The same circularity of the grains implies that the grain shape does not affect the difference in solidification performance between two slags. The investigation was conducted on the internal micro-structural characteristics in the steel slag-mixed clay specimen. By X-ray CT scanning on the specimen before and during the shear, the uniform distribution was identified to confirm the homogeneity of the specimen. It was clearly observed that soft specimen manifested ductile behavior while stiff specimen showed brittle behavior by the formation of the cracks.